

**Fermilab**  
ES&H Section

**R.P. NOTE 148**

**SUMMARY OF CY 2003 TOTAL EFFECTIVE DOSE EQUIVALENT**

**Susan McGimpsey**

**April 2004**

Prepared by: \_\_\_\_\_  
S. McGimpsey, Dosimetry Program Mgr.

Date \_\_\_\_\_

Reviewed by: \_\_\_\_\_  
Tim Miller, Assoc. Head of Medical and  
Admin. Support Services

Date \_\_\_\_\_

Approved: \_\_\_\_\_  
Don Cossairt, Assoc. Head of Radiation Protection

Date \_\_\_\_\_

Approved: \_\_\_\_\_  
Bill Griffing, ES&H Section Head

Date \_\_\_\_\_

## **R.P. NOTE 148**

### **SUMMARY OF CY 2003 TOTAL EFFECTIVE DOSE EQUIVALENT**

**Susan McGimpsey**

**April 2004**

#### **1. OVERVIEW**

The mission of Fermi National Accelerator Laboratory is to advance the understanding of the fundamental nature of matter and energy by conducting research at the frontier of high energy physics. Today this involves producing and accelerating the largest numbers of protons ever recorded in the history of the Laboratory in order to achieve the sensitivities needed to resolve the important scientific questions under investigation. This demand for increased intensity and luminosity is necessary to support both collider physics experiments that are operating at the current energy frontier, as well as neutrino physics experiments that require unprecedented beam intensities. However, the ability to deliver even larger numbers of high energy protons is limited by activation and radiation damage to accelerator components. Maintenance activities to repair such components also may lead to radiation doses to personnel. Cossairt has analyzed historic trends in radiation exposures at Fermilab.<sup>1</sup> The purpose of this note is to analyze the dosimetry results for CY03 in the context of the overall Fermilab operational program.

As at most large particle accelerators worldwide, most radiation exposure is received from maintenance activities conducted with the beam turned off. At Fermilab essentially no personnel exposure is due to prompt radiation fields present with the accelerator turned on due to well-designed bulk shielding and extremely effective implementation of radiation safety interlocks. As an important part of normal operation of the Tevatron Collider program and the MiniBooNE neutrino physics experiment, the Laboratory must conduct periodic major shutdowns to maintain and repair existing equipment and upgrade older beam line components to meet the goal of higher beam intensities. While improved accelerator performance is the primary goal of these shutdowns, the reduction of future radiation exposures through better component design and improved reliability was viewed by all personnel involved as being of singular importance. It was recognized by all involved that improvements to the accelerators necessary to meet programmatic goals would require some additional worker exposures compared with those experienced in recent years. Thus, the careful planning of the requisite work tasks is given considerable scrutiny in order to maintain personnel radiation exposures as low as reasonably achievable (ALARA) in accordance with overall implementation of Fermilab's Integrated Safety Management (ISM) program.

## **2. DESCRIPTION OF MAJOR SHUTDOWN TASKS**

During calendar year 2003 there were two major shutdowns. The first occurred during the first quarter beginning January 13 and ending January 31. The second shutdown overlapped the third and fourth quarters beginning September 8 and ending November 17. The majority of the work performed during these shutdown periods involved Accelerator Division personnel, although personnel from other divisions/sections assisted as necessary. These individuals were fully trained in radiological work procedures in general and were thoroughly briefed in the specifics of each job task. The shutdowns involved several major projects, many of which, particularly in the Booster synchrotron, were aimed at reducing beam losses as an essential ingredient in improving performance and increasing deliverable proton intensities. Reducing beam losses reduces radioactivation of beamline components and potential radiation dose to personnel who must maintain the accelerators in the future. The Booster was a major focal point of effort because this part of the accelerator is responsible for delivering protons to both the neutrino experiment MiniBooNE and the RUN II B Collider Physics Program. Also, the Booster, now over age 30 years, is the oldest accelerator at Fermilab that has not experienced a significant upgrade or replacement.

A brief summary of major shutdown activities, compiled by the Accelerator Division, is provided below. The intent of these summaries is to supply the reader with some idea of how this body of work fits into the overall goals of improved accelerator performance, enhanced reliability, and better control of present, and future, radiation exposures. All of these tasks were necessary to achieve the challenging goals of the physics research program and most of them are likely to result in reduced radiation exposures during future maintenance activities.

### **Booster “Candy Canes”**

The name “Candy Canes” refers to the plastic hoses in the water manifolds of the Booster magnets. Each of the 96 Booster dipoles has four of these hoses. The hoses at the now elevated levels of beam intensities were found to be failing due to radiation damage. During the shutdown, the majority of these hoses were replaced by new ones made of material more tolerant of the high radiation levels present during operations to decrease the potential for future failures. Fewer failures should translate into less dose to workers in the future.

### **Booster EPB-EDWA magnets**

The four magnets at the beginning of the main extraction line from the Booster, known as the Booster EPB-EDWA magnets, were replaced with new magnets with larger apertures. This is anticipated to reduce radiation levels in the tunnel and surrounding soil shielding as intensity demands increase, since fewer protons will be lost in the magnets.

### **Booster MP01 Valve Repair**

A failed vacuum valve was replaced in one of the extraction regions, where residual radiation levels were elevated. This task, though necessary to continue operations, by itself might not appear to directly lead to reduced radiation dose to workers. However, its completion should result in an incremental improvement in reliability. Other shutdown tasks should also result in reduced future radiation levels in this region of the Booster.

### **Linac Lambertson**

The so-called Lambertson magnet that steers the beam from the Linac toward the Booster was replaced with a new one with better magnet properties. This is anticipated to reduce losses of beam in the beam line and thus the associated doses to the personnel that need to occasionally work in the area.

### **Booster Collimators**

A large collimation system designed to collect the protons which were previously lost in an uncontrolled fashion around the Booster ring was installed. It is hoped that these collimators, designed to provide significant self-shielding, will greatly reduce losses and activation throughout the Booster, not only for current operation but as intensity demands increase. This new system has been carefully designed using Monte Carlo techniques to minimize the loss of beam and to localize significant amounts of unavoidable beam loss to well-shielded components in order to reduce the ambient radiation levels at other locations elsewhere throughout the Booster.

### **Booster MP02/Long 3**

A rearrangement of the magnets at the main extraction section of the Booster was performed. This was done to address identified beam optics problems. The new configuration should result in better efficiency and lower losses in the future as intensity demands increase. It was carefully designed by means of extensive calculations.

## **3. RADIATION MONITORING/DOSE RESULTS**

Fermilab continues to diligently manage a Radiation Protection Program as part of ISM to control radiation doses to personnel and keep exposures ALARA. Figure 1 shows the integrated intensities of protons accelerated by the Booster synchrotron and the quarterly total effective dose equivalent (TEDE) results for the Laboratory as a whole as a function of time. Figure 2 shows the total TEDE per proton accelerated in the Booster both on a quarterly basis and annually averaged for each calendar year. The value of TEDE per proton accelerated by the Booster is a useful figure of merit at Fermilab, since all of the protons used in the high energy physics research program at Fermilab are accelerated by this stage of the accelerator complex. Also, from experience and current measurements it is obvious that the Booster is the location of the majority of proton beam loss. In Figure 2, the annual average is a better indicator than are

the quarter-by-quarter values because it removes the effect that during shutdowns of several weeks duration, most of the dose is being received while little or no beam is being accelerated. It is clear that over recent past years the doses received by personnel are decreasing with time as the proton numbers increase during routine accelerator operations. The typical TEDE for a quarter in the recent past has been about 3.5 person-rem. Table 1 shows that major shutdowns such as those which took place during CY 2003 have a tendency to raise this total significantly. Tables 2 and 3 show that there were some more individual doses in the 10-20 mrem range and a few higher doses that are not present during routine accelerator operations. However, doses to individuals still remain generally low compared to levels of regulatory concern or with natural background levels.

While the Laboratory pursues increased beam intensities, it continues to monitor radiation doses to personnel, and during calendar year 2003 Fermilab experienced a significant increase in the TEDE. Careful evaluation of the comparison between the TEDE for CY 2002 and CY 2003 indicates that the two necessary shutdowns of the accelerators for upgrades, maintenance and repair work, as expected from past experience, are largely responsible for this increase. Figure 3 shows the dose distribution for each quarter of 2003 for the Fermilab as a whole and for the Accelerator and Particle Physics Divisions whose personnel carried out the vast majority of the shutdown tasks. Figure 4 shows how shutdown work affected the collective dose to specific Accelerator Division work groups involved in the majority of these tasks. Appendix A provides the dosimetry badge series code for these Accelerator Division departments.

Thus having two shutdowns for calendar year 2003 increased the TEDE by approximately 11 person-rem from the previous year. Although there was an increase in the TEDE, the Accelerator Division is recognized for efforts made to keep these doses as low as reasonably achievable (ALARA). An important component of this effort was the conduct of job-specific ALARA planning for each major task. Also, some tasks that were likely to be “high dose” were deferred to the latter portion of the shutdown in order to take advantage of radioactive decay to reduce the radiation levels involved. The job-planning efforts included detailed estimates of the individual doses associated with subtasks. During the work, supplementary dosimeter readings were recorded on a daily basis. It turned out that the dose predictions were quite accurate as verified by these supplementary dosimeter readings. The supplementary dosimeter results were also in good agreement with the results measured by the DOELAP-accredited dosimeter badges, received at a later time following each quarterly badging period. Though these improvement projects raised the TEDE during CY 2003, the long term benefits will prove invaluable for accelerator performance and dose reduction in the future. Thus, an investment has been made in future improved operations with radiation exposures maintained ALARA.

I would like to thank Don Cossairt, Jean Slaughter, Mike Syphers and Tim Miller for their helpful comments and suggestions in preparing this document.

#### Reference:

1. J.D. Cossairt, 2003, RP Note 142, *Long Term Trends in Radiation Exposures at Fermilab*.

**Figure 1**  
**Quarterly Totals of Protons Accelerated by the Booster and Labwide TEDE**

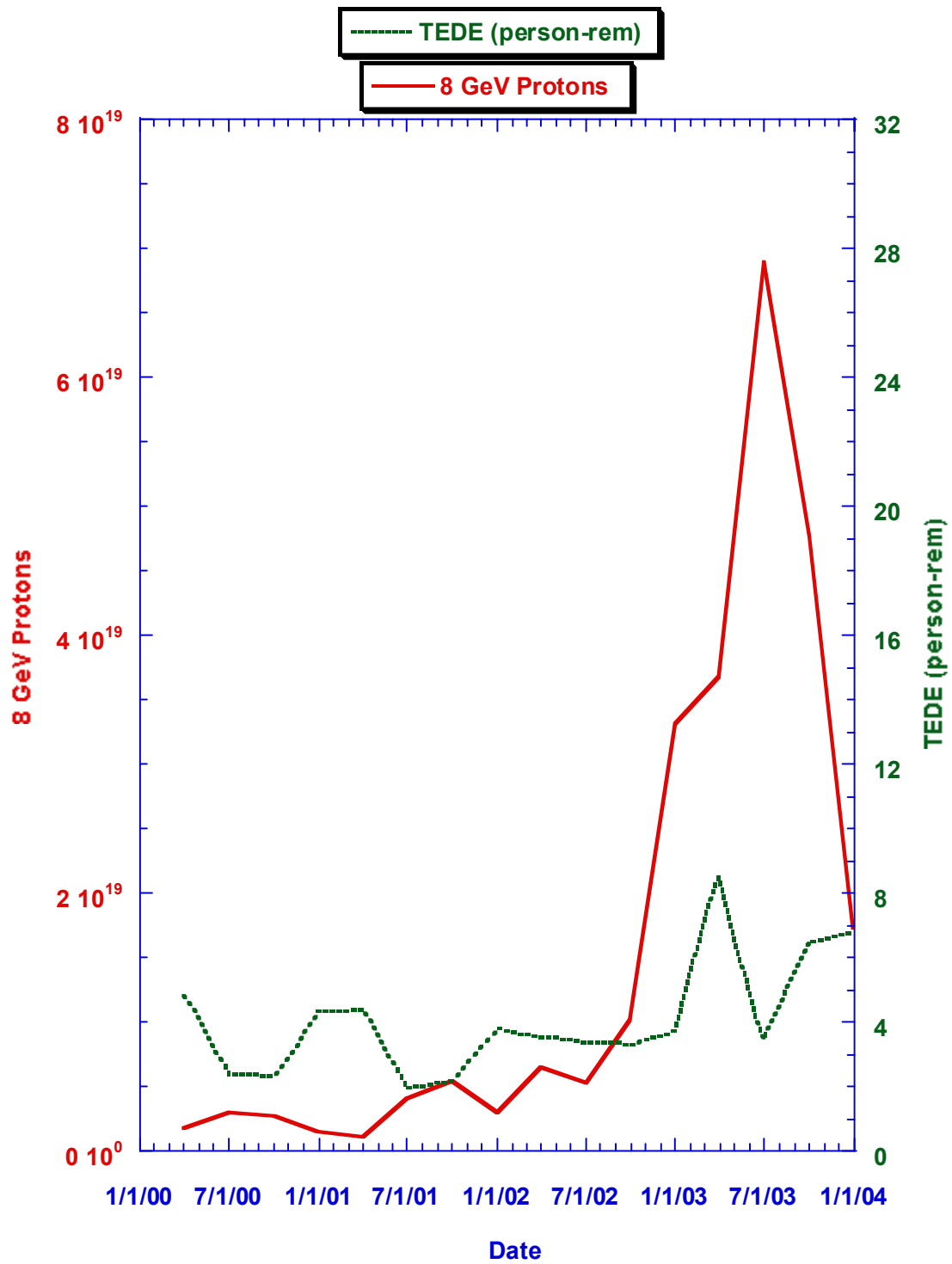
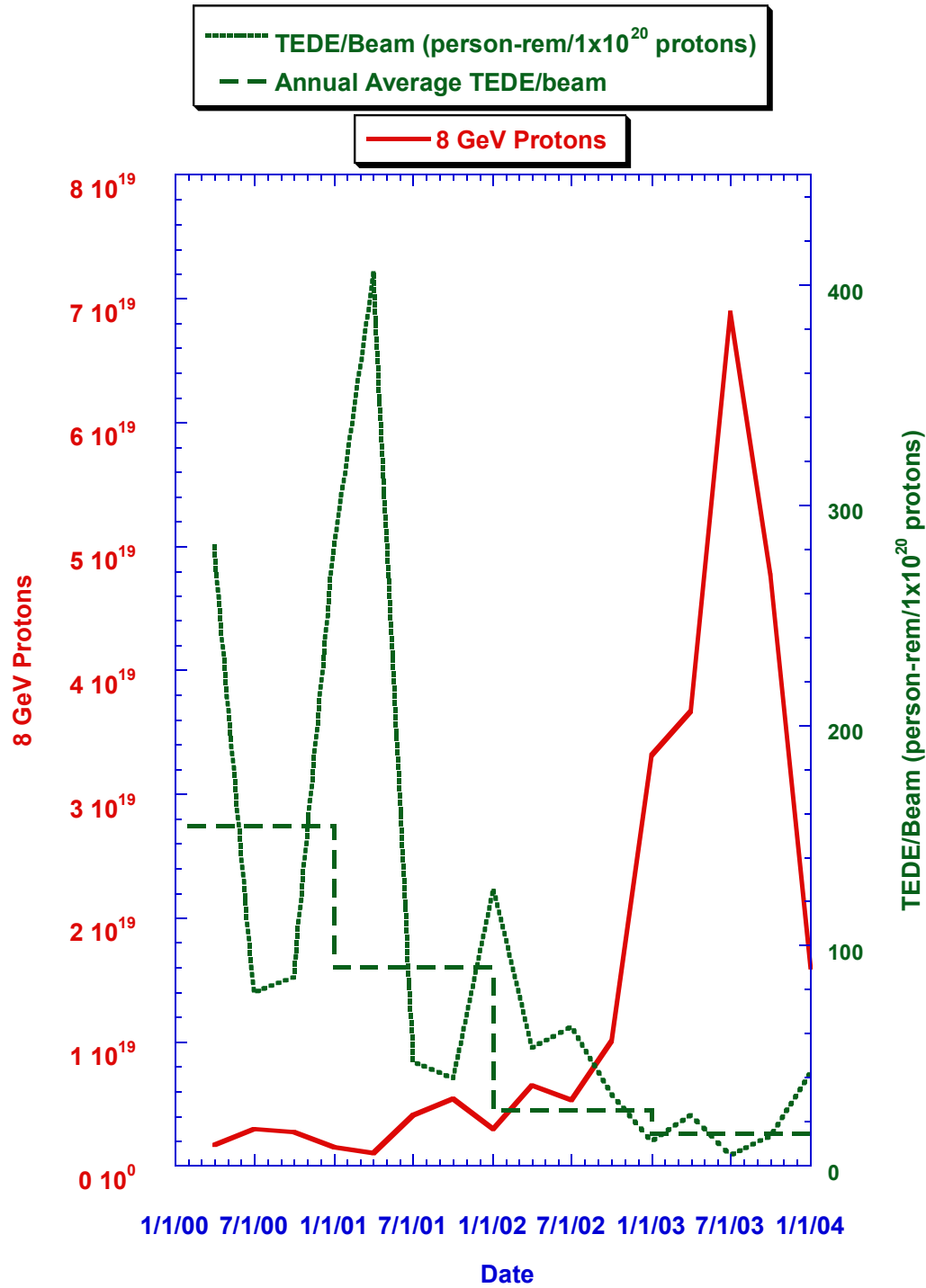


Figure 2  
Quarterly Totals of Protons and Labwide TEDE per Proton Accelerated by the Booster



**Table 1 Quarterly TEDE Results for CY 2002 and CY 2003**

	CY 2002	CY 2003	Increase in TEDE
	Person-Rem	Person-Rem	Person-Rem
1 <sup>st</sup> Quarter	3.51	8.48	4.97
2 <sup>nd</sup> Quarter	3.37	3.46	~ 0
3 <sup>rd</sup> Quarter	3.29	6.50	3.21
4 <sup>th</sup> Quarter	3.75	6.84	3.09
<b>YEARLY TOTAL</b>	<b>13.92</b>	<b>25.28</b>	<b>11.36</b>

**Table 2 Distribution of Individual Doses in CY 2003**

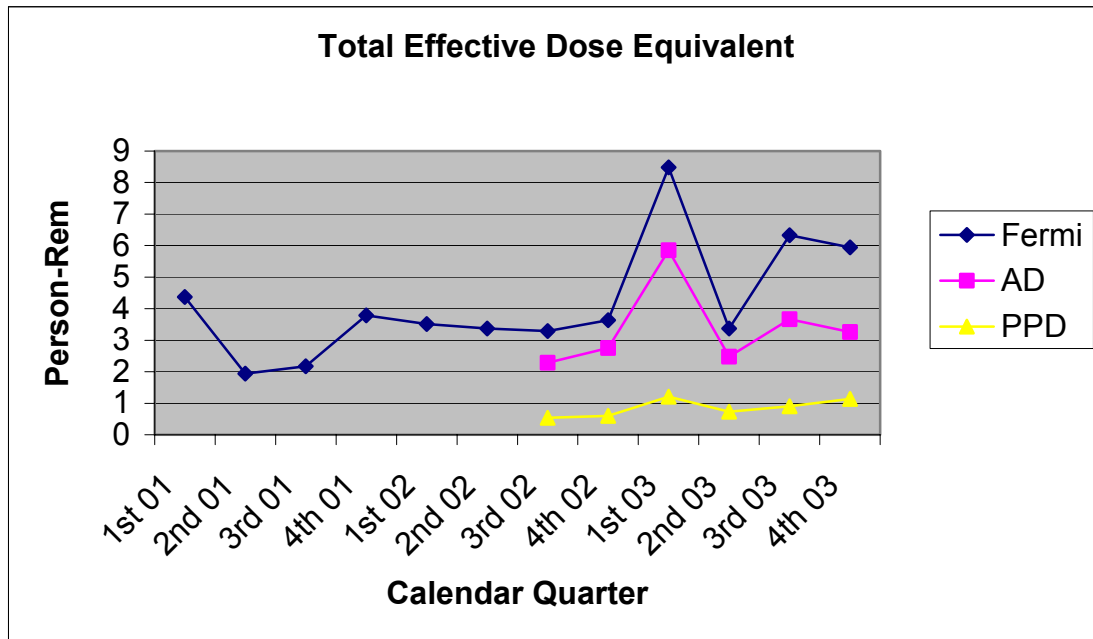
Dose Range (mrem)	1st Qtr 2003 Number of Doses	2nd Qtr 2003 Number of Doses	3rd Qtr 2003 Number of Doses	4th Qtr 2003 Number of Doses	CY 2003 Total
10 - 20	236	147	251	102	736
30 - 40	43	23	24	43	133
50 - 60	17	5	11	21	54
70 - 80	9	1	6	5	21
90 - 100	6	4	5	5	20
> 100	10	0	6	5	21
Highest Dose	280	100	230	270	

**Table 3 Distribution of Individual Doses in CY 2002**

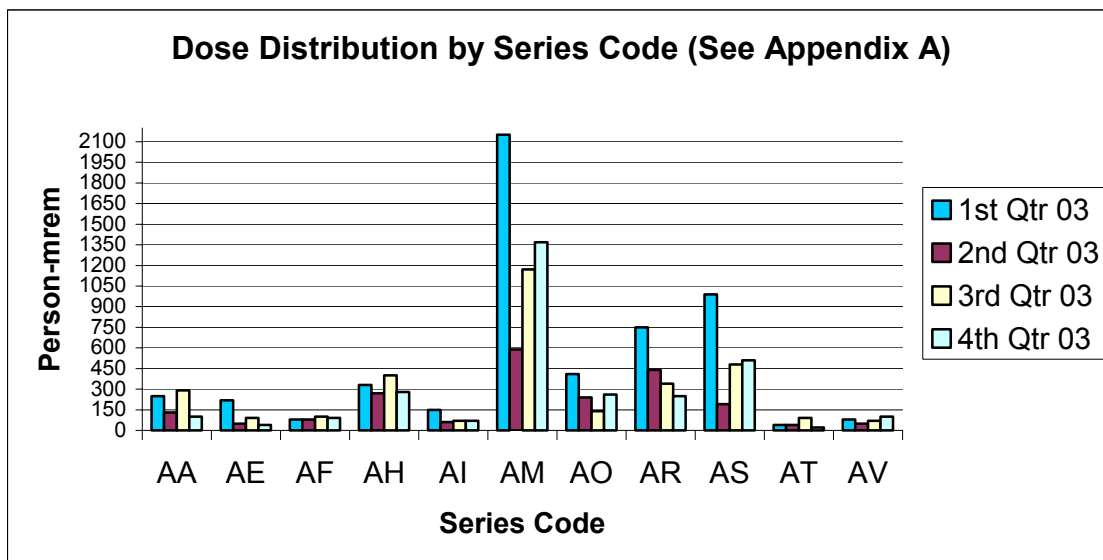
Dose Range (mrem)	1st Qtr 2002 Number of Doses	2nd Qtr 2002 Number of Doses	3rd Qtr 2002 Number of Doses	4th Qtr 2002 Number of Doses	CY 2002 Total
10 - 20	169	163	148	139	619
30 - 40	9	8	19	14	50
50 - 60	6	4	5	8	23
70 - 80	2	2	3	9	16
90 - 100	1	1	0	3	5
> 100	4	3	2	0	9
Highest Dose	200	140	170	100	



**Figure 3**  
**TEDE Results for Fermilab, Accelerator Division, and Particle Physics Division**



**Figure 4**  
**TEDE Trends in Accelerator Division by Working Group in CY 2003**



## Appendix A

badge code	DEPT
AP	AD/ACCEL_INTERGRATION
AT	AD/ENG/CONTROLS
AC	AD/ENG/CRYO
AE	AD/ENG/EE SUPPORT
AZ	AD/ENG/INSTRUMENTATION
AM	AD/ENG/MECH SUPPORT
AR	AD/ENG/RF
AG	AD/ENGINEERING SUPPORT
AH	AD/ES&H
AB	AD/EXTERNAL BEAMLINE
AI	AD/MAIN INJECTOR
NTF	AD/NTF
AN	AD/NUMI DEPT
AO	AD/OPS
AA	AD/PBAR
AQ	AD/PI
AS	AD/PROTON
AF	AD/RECYCLER
AV	AD/TEV
AQ	AD/HEADQUARTERS